Report as of FY2008 for 2008PA88B: "Seeing into the subsurface: Detecting and visualizing preferential flow in situ using innovative approaches"

Publications

- Articles in Refereed Scientific Journals:
    - ♦ Lin, H.S. 2009. Earth s Critical Zone and Hydropedology: Concepts, Characteristics, and Advances. Hydrology and Earth System Science Dis. 6:1-37.
- Book Chapters:
    - ♦ Lin, H.S., E. Brook, P. McDaniel, and J. Boll. 2008. Hydropedology and Surface/Subsurface Runoff Processes. In M. G. Anderson (Editor-in-Chief) Encyclopedia of Hydrologic Sciences. John Wiley & Sons, Ltd. DOI: 10.1002/0470848944.hsa306.

Report Follows

PRINCIPAL FINDINGS AND SIGNIFICANCE

The lack of an effective means for detecting and visualizing subsurface flow dynamics has constrained our understanding and predicting of vadose zone processes such as subsurface stormflow and groundwater recharge. Growing evidence suggest that subsurface flow network is a key to understanding hydrologic processes including hillslope threshold behavior. The dynamic origin of network structures in soils and hydrologic systems and recurrent patterns of self-organization are the subjects of recent research and model development.

Subsurface lateral flow in the catchment has been observed to contribute substantially to direct runoff. But understanding the occurrence and intensity of subsurface lateral flow is difficult because of the subsurface complexity and the lack of appropriate tools to identify this complexity. In this study, we innovatively used time-lapsed ground penetrating radar (GPR) in combination with real-time soil water monitoring to identify subsurface flow regime in different hillslopes and soil types at the Shale Hills Catchment. The results of this study have significant implications for developing a next generation of hydrologic models that explicitly consider flow pathways, patterns, and flow configuration evolution.

Ground Penetrate Radar provides a non-invasive way to reveal the subsurface complexity. We have demonstrated that GPR is suitable to identify subsurface structure in this landscape. However, static radargram only provides a qualitative description of subsurface characteristics. In this study, we developed time-lapsed GPR with soil water sensors to identify subsurface flow patterns in real time. A 3 by 4 meter grid was established along several hillslopes. In each grid, multiple ECH_2O-TE probes were installed at different depths (5, 10 and 30 cm) and the probes were connected to CR1000 datalogger to record the soil water dynamics at 2-minutes interval. The GPR scan was along downslope direction and the space interval was 0.1 m. The 400 MHz GPR was first used to scan the grid to obtain initial subsurface state. Then, a known volume of water waas carefully poured onto the soil surface at the upper portion of the grid. Subsequent GPR scans were then conducted along the same traverse line 5, 10, 20, 30, 40, 50 and 60 minutes later. Results indicated that radiograms were quite different before and after water infiltration. Electromagnetic velocity of GPR was obtained through the detection of direct ground wave, and then was transformed to water content using Topp's equation. Inverse distance weight method was used to interpolate the derived soil moisture and compared with the soil water content measured by ECH_2O-TE probes. By comparison with time-lapsed soil moisture map, it was possible to determine the subsurface flow pattern across the hillslope transects. This study improves the understanding of subsurface flow pattern in the Shale Hills Catchment and will enhance more realistic hydrological model development. In addition, we have developed many 3D (X, Y, Z; or X, Y, and time) and 4D (X, Y, Z, and time) animations of subsurface preferential flow at the pedon and hillslope scales based on the database collected from this project, which benefits classroom teaching and public education via "seeing is believing." For example, one of such animations is viewable and downloadable at http://hydropedology.psu.edu/.

Graduate student Jun Zhang and NRCS collaborator Jim Doolittle were working on GPR scanning of a hillslope at the Shale Hills Catchment.

Experimental setup of time-lapsed GPR scanning and real-time soil moisture monitoring with introduced water infiltration in a hillslope at the Shale Hills Catchment.
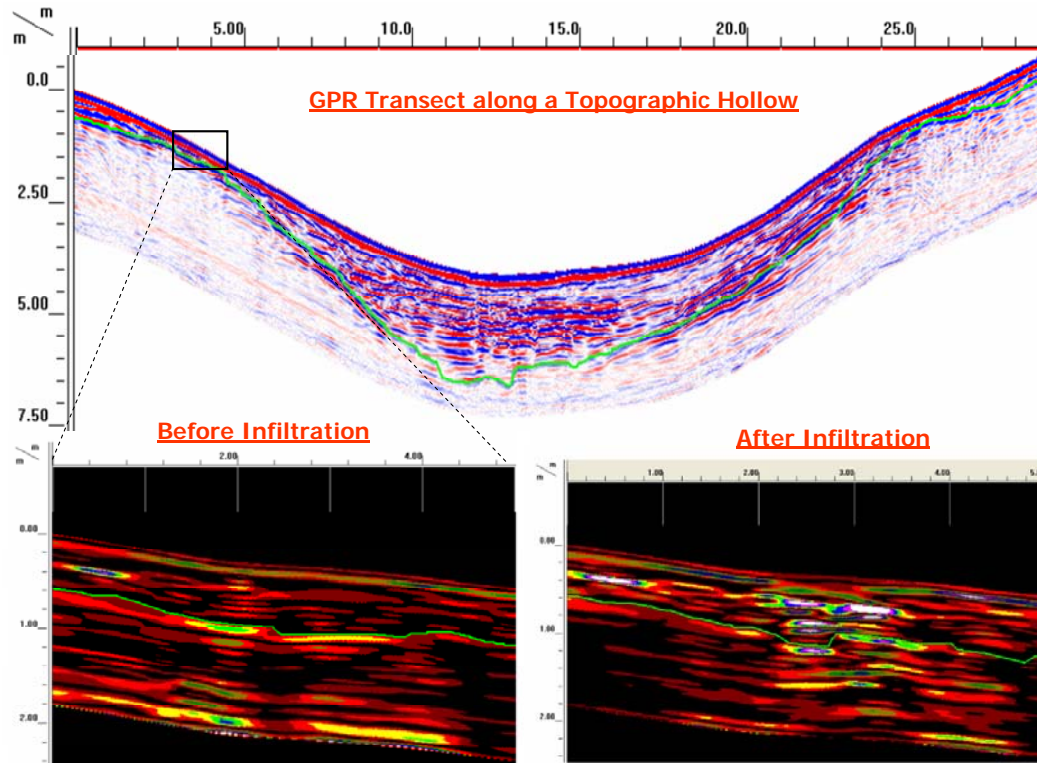
A terrain-corrected ground penetrating radar (GPR) image collected at the Shale Hills Catchment along a topographic hollow (orthogonal to its long axis). The green line indicates the interpreted approximate soil-bedrock interface. The zoom-in images show a section of the hillslope before (left) and after (right) ten gallons of water infiltrated into the soil between the 2 and 3 m distance marks.
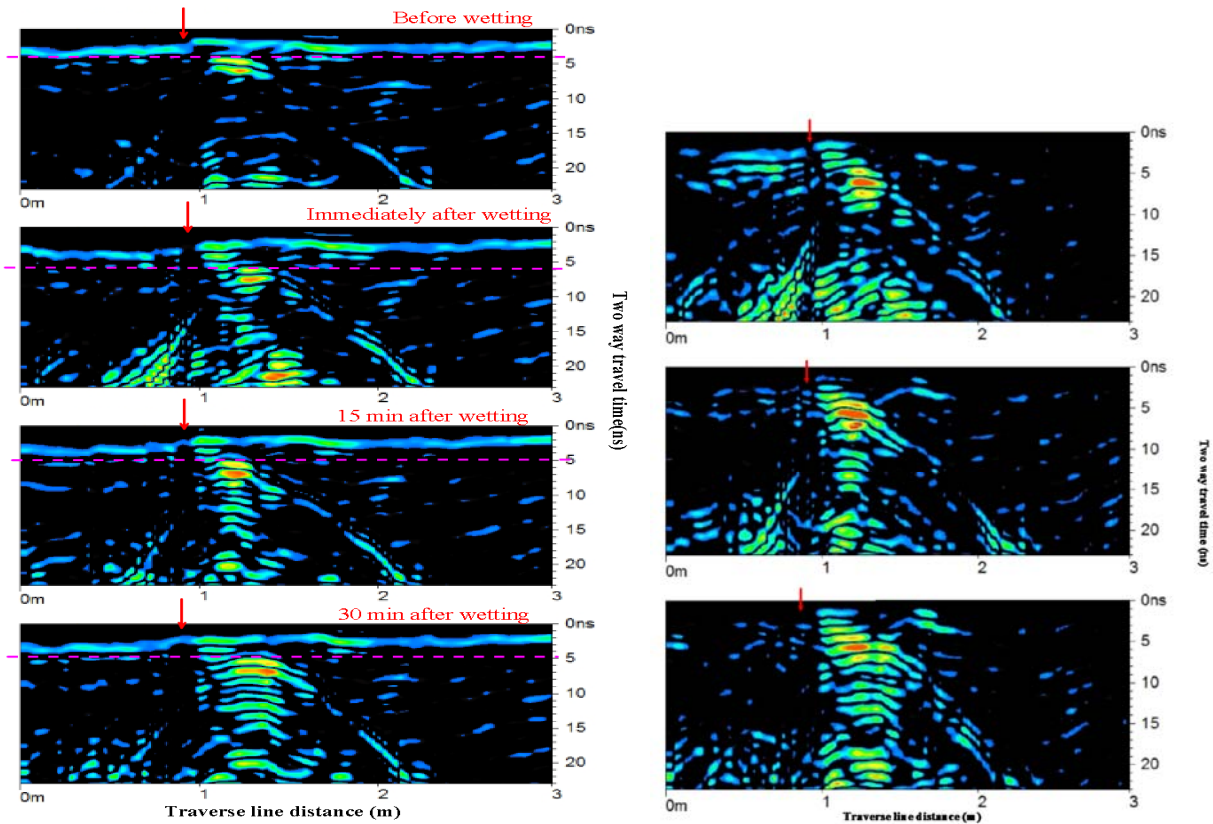
A: Time lapse GPR image before and after infiltration. Red arrow indicates the location of infiltration intake. Dash line is the two way travel time to the apex of hyperbola, which indicates the depth of buried metal plate used for GPR image calibration.

B: Difference between radargrams before infiltration and after 0, 15, 30 minutes infiltration, respectively (from top to bottom)